Bali Medical and Wellness Journal
bmw-journal.com

Article

Implications of Integrating Nutrigenomic Aspects on Training Ability and Recovery in Athletes: A Literature Review

I Putu Gede Windhu Saputra

Siloam Hospitals Denpasar, Bali, Indonesia
Correspondence: windhusaputra@gmail.com

ABSTRACT
Background: Nutrition impacts sports performance significantly, influencing each athlete differently. Factors such as age, ethnicity, and genetics affect how athletes respond to nutrition.
Objective: This review investigates how incorporating nutrigenomics enhances training and recovery in athletes.
Methods: A systematic search following PRISMA 2020 guidelines was conducted to find relevant studies that examine the impact of genetic variations on nutritional effects related to athletic performance and recovery. The included articles are non-observational studies selected based on specific inclusion and exclusion criteria and were qualitatively analyzed..
Results: The review included nine studies, primarily clinical and randomized controlled trials, conducted in Iran, Brazil, and Canada. Most studies focused on male athletes aged 15 to 40 years. The studies suggest that caffeine and vitamin D effects on performance may vary based on individual genotypes, but specific genes do not consistently influence these effects.
Conclusion: Adopting genetic-based nutrition and supplementation approaches holds promising potential for optimizing athletic performance by tailoring nutrient intake to individual genetic profiles.

Keywords: Athlete, genetic, nutrition, literature review

Citation: Saputra, I P. G. W. Implications of Integrating Nutrigenomic Aspects on Training Ability and Recovery in Athletes: A Literature Review. Bali Medical and Wellness Journal **2024**, 1 (2), 51-59.

Submitted: July 23, 2024
Revised: August 23, 2024
Accepted: October 21, 2024
Published: November 1, 2024

INTRODUCTION

Nutrition and environment are key factors that influence human health. Recent research has shown a significant relationship between dietary components and DNA metabolism, with various food factors acting as substrates in metabolic pathways. However, our understanding of how nutrient deficiencies or excesses affect DNA replication is still limited (Heyn et al., 2013). Nutrigenomics is an emerging field that combines nutrition and genetics. It initially focused on how nutrition affects gene expression but has since expanded to study how nutritional factors can protect our genetic material. This broader scope offers new opportunities in many areas, including athlete nutrition, potentially changing how we approach training and recovery (Guest et al., 2019).

Nutrigenomics has applications in various health sectors, including sports. Nutrition significantly impacts athletic performance, but individual responses to nutrition vary (Suleman et al.,2024). Factors such as age, ethnicity, and genetics play important roles in how an athlete's body responds to food. Genetic variations affect how a person absorbs, metabolizes, uses, and excretes nutrients, influencing the relationship between diet and metabolic pathways. By examining an athlete's genetic profile, we can provide personalized dietary recommendations that may lead to more effective results (Palou, 2007).

As we delve deeper into the era of personalized medicine and nutrition, the integration of nutrigenomic principles in athletic training and recovery strategies stands out as a frontier with immense potential. This review aims to explore the multifaceted implications of incorporating nutrigenomic insights into athletic training regimens and recovery protocols. By examining the current state of research and its practical applications, this review seeks to illuminate how this innovative field could transform our understanding of athletic performance, paving the way for more targeted, efficient, and effective approaches to training and nutrition in sports.

METHODS

This systematic review was conducted using rigorous scientific methods to identify, assess, and interpret relevant findings on the topic. The study adhered to the PICOS (Population, Intervention, Comparison, Outcome, Studies) framework to ensure comprehensive inclusion of relevant studies. All search procedures followed the 2020 PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines, ensuring the review's validity and reliability.

Study selection

Sourced studies were obtained from online databases such as PubMed (MEDLINE), Science Direct, Cochrane Library, and ProQuest. These studies evaluated polymorphisms and genetic variants related to nutrition and their effects on athletic performance and recovery. The review focused on sports athletes. Studies were excluded if they (1) analyzed genetic variants without relevant nutritional analysis, (2) did not report therapy response parameters, or (3) used an observational study design.

Study Search

The study search utilized keywords developed from the PICOS framework to optimize search results. The process began with selecting keywords using Medical Subject Headings (MeSH). Subsequently, advanced search techniques, bibliographic searches, and Boolean operators (AND, OR, NOT) were employed. The search terms included: "(polymorphism) AND (nutrition) AND ((genetic) OR (caffeine) OR (vitamin D)) AND (athlete)".

Data extraction and study quality assessment

Critical appraisal was used to assess the quality of articles for inclusion in the review. Data extraction was performed independently. The study quality was evaluated using the New Ottawa Castle Scale for clinical trials, covering selection, comparability, and outcome. Articles meeting quality criteria were included.

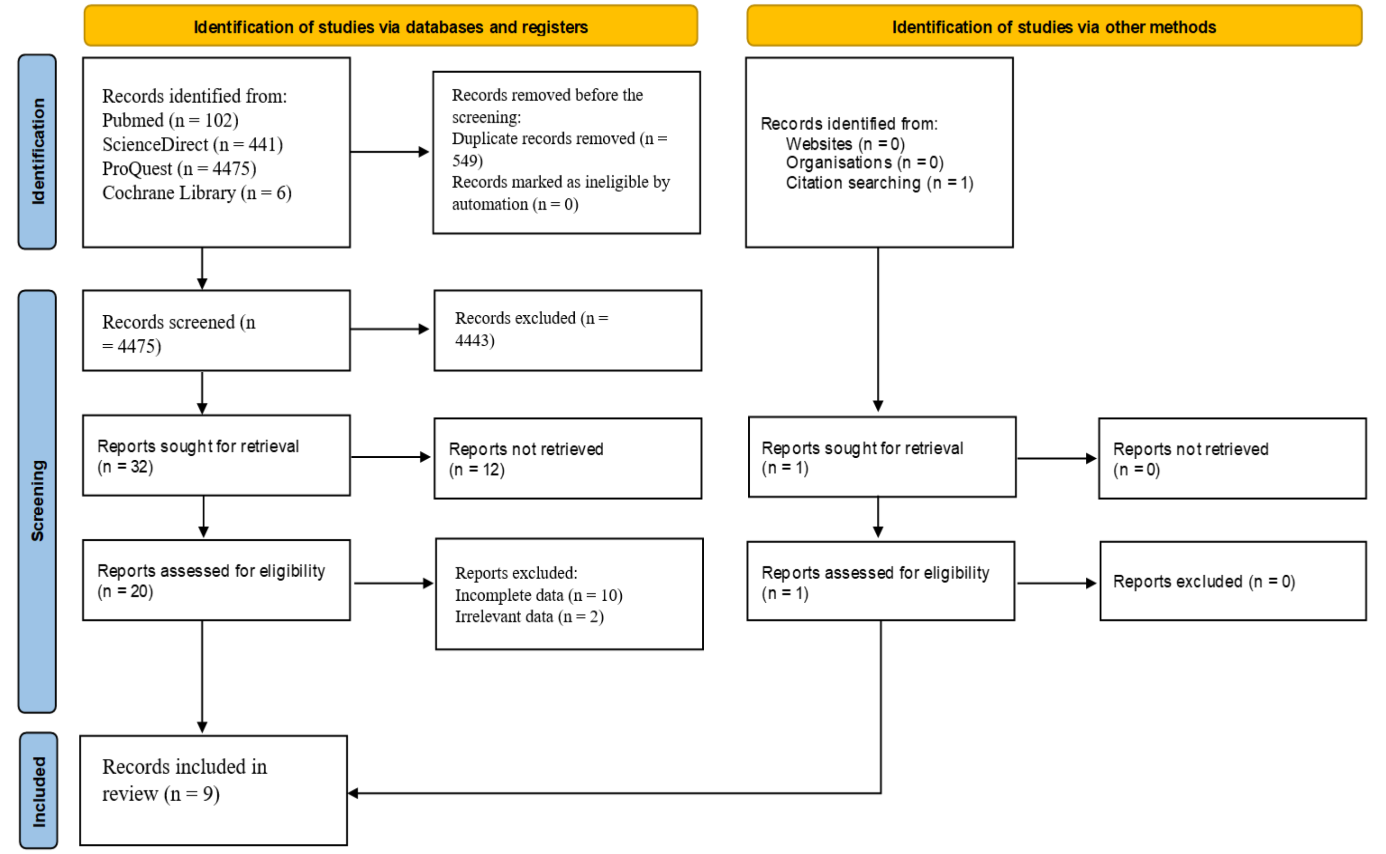
Data analysis

Data analysis was carried out by systematically integrating and describing all data to obtain conclusions. The data consists of research characteristics (name of primary author, year of publication, research location, and population size) and population characteristics (type of athlete, age and gender characteristics, and primary research results). The data is presented in a table (synthesis matrix) to facilitate analysis.

RESULTS

Literature Searching

In this study search, 240 articles were retrieved from databases including PubMed, ScienceDirect, Cochrane, and ProQuest. After using citation management software to remove duplicates, 120 articles remained. Screening of titles and abstracts led to 20 articles being assessed for eligibility. Of these, 12 were excluded due to incomplete or irrelevant data. Consequently, a qualitative analysis was conducted using the 9 studies that met the inclusion criteria. The PRISMA guidelines were followed during the study selection process, as illustrated in Figure 1.



*Consider, if feasible to do so, reporting the number of records identified from each database or register searched (rather than the total number across all databases/registers).
**If automation tools were used, indicate how many records were excluded by a human and how many were excluded by automation tools.

From: Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ 2021;372:n71. doi: 10.1136/bmj.n71. For more information, visit: http://www.prisma-statement.org/

Figure 2. PRISMA Flowchart

As shown in Table 1, the majority of the included studies originated from Iran, Brazil, and Canada, with two studies each. Additionally, there was one study from Russia, Turkey, and the USA respectively. Most of the research focused on male athletes in their prime, with an age range of 15 to 40 years.

Table 1. Characteristic of the study

Author, years	Country	Population Size	Type of Athlete	Mean Age	Gender
Glaister et al., 2021(Glaister et al., 2021)	USA	66	Cyclists	41.9 ± 8.6 years	Male
Guest et al., 2022(Guest et al., 2022)	Canada	100	Cyclists	25 ± 4 years	Male
Wong et al., 2021(Wong et al., 2021)	Canada	102	Non-specified	25 ± 4 years	Male
Minaei et al., 2022(Minaei et al., 2022)	Iran	16	Non-specified	21.6 ± 7.1 years	Male
Spinelli et al., 2020(Spineli et al., 2020)	Brazil	100	Non-specified	15 ± 2 years	Male
Bulgay et al., 2023(Bulgay et al., 2023)	Turkey	60	Non-specified	25.1 ± 4.8; years	Male
Rahimi et al., 2024(Study et al., 2024)	Iran	30	Non-specified	21.7 ± 4.1 years	Male
Rahimi et al., 2023(Rahimi et al., 2023)	Russia	134	Non-specified	Female: 28.4 ± 7.1 years Male: 31.4 ± 8.6	Male and Female
Spinelli et al., 2024(Spineli et al., 2024)	Brazil	75	Non-specified	DD: 16±1.7 years DI: 16±2.0 years II: 15±1.7 years	Male

Synthesis of Findings

As shown in table 2, the studies reviewed highlight the interaction between specific gene variants and the effects of caffeine and vitamin D on athletic performance.

Caffeine and Genetic Variability

Several studies highlight the significant interaction between the CYP1A2 gene and the ergogenic effects of caffeine. Research by Wong et al. (2021) and Minaei et al. (2022) demonstrates that athletes with particular CYP1A2 genotypes experience greater benefits from caffeine, such as enhanced muscle strength and improved anaerobic performance. However, Glaister et al. (2021) found no significant impact of CYP1A2 or ADORA2A genotypes on performance in response to caffeine, suggesting that findings may vary based on specific contexts or methodological differences. Further investigation into the ADORA2A gene by Guest et al. (2022) and Rahimi et al. (2023, 2024) reveals that genetic variations could influence performance enhancements and physiological responses, particularly concerning hormonal and anti-inflammatory effects. Interestingly, Spinelli et al. (2020) reported that adolescent athletes benefited from caffeine without the influence of CYP1A2 genotypes, indicating possible age-related factors in genetic effects. Additionally, the ACE gene variants explored by Spinelli et al. (2024) showed that athletes consuming caffeine experienced improvements in aerobic power and reduced perceived exertion, emphasizing the significant role of genetic factors in aerobic activities.

Vitamin D and Genetic Influence

Regarding vitamin D, Bulgay et al. (2023) identified the VDR rs2228570 polymorphism as a potential influencer of competitive performance among elite athletes. This genetic variant may impact how the body utilizes vitamin D, affecting muscle function and bone health. Across these findings, genetic variations significantly impact how nutritional elements like caffeine and vitamin D affect athletic performance. This suggests that personalized nutrition strategies, tailored to individual genetic profiles, could optimize performance outcomes for competitive athletes.

Table 2. The summary of the effect of genetic profiling and nutritional intake on athletes.

Author, year	Gene	Nutrition	Results
Glaister et al., 2021	ADORA2A CYP1A2	Caffeine	ADORA2A and CYP1A2 genotypes do not affect caffeine's impact on exercise performance.
Guest et al., 2022	CYP1A2	Caffeine	CYP1A2 and HTRA2A influence performance enhancement from caffeine in endurance activities.
Wong et al., 2021	CYP1A2	Caffeine	CYP1A2 genotype affects caffeine's enhancement of muscle strength.
Minaei et al., 2022	CYP1A2	Caffeine	CYP1A2 genotype influences caffeine's boost to anaerobic performance.
Spinelli et al., 2020	CYP1A2	Caffeine	Caffeine enhances performance in adolescents regardless of CYP1A2 genotype.
Bulgay et al., 2023	VRD	Vitamin D	VDR polymorphism affects vitamin D's influence on athletic performance.
Rahimi et al., 2024	ADORA2A	Caffeine	ADORA2A genotype alters caffeine's hormonal impact during exercise.
Rahimi et al., 2023	ADORA2A	Caffeine	ADORA2A TT genotype provides anti-inflammatory benefits from caffeine.
Spinelli et al., 2024	ACE	Caffeine	ACE genotypes improve aerobic power and reduce exertion with caffeine use.

DISCUSSION

The studies reviewed demonstrate that genetic variation plays a significant role in modulating athletes' responses to nutrition and supplementation, particularly with caffeine and vitamin D. Variations in genes like CYP1A2, ADORA2A, and ACE influence caffeine metabolism, affecting muscle strength, anaerobic performance, and aerobic power. These findings suggest that personalized nutrition strategies can be developed by understanding an individual's genetic profile, potentially enhancing performance and recovery. Similarly, genetic differences in the VDR gene impact vitamin D metabolism and its effects on muscle function and bone health. These insights emphasize the need for personalized dietary recommendations in sports nutrition, aiming to optimize athletic performance and improve overall health outcomes.

Nutrigenomics, derived from "nutrition" and "genomics," studies the interaction between nutrients and genes, affecting human health. It examines how nutrients, both micronutrients and macronutrients, influence metabolic pathways and homeostasis (Communications, 2016). The field involves transcriptomic, proteomic, and metabolic processes, showing how nutrients can alter gene expression at levels like regulation and protein function. Genomics employs techniques like DNA sequencing to analyze genome structures and functions (Celis-Morales et al., 2017).

Genetic information, such as genotype, is crucial for designing personalized dietary recommendations for athletes, enhancing adherence to dietary changes (Wong et al., 2021). Nutrients impact performance, with micronutrients like vitamins A, C, D, and caffeine, and macronutrients like proteins and fats playing significant roles (Spronk et al., 2015). Genetic variation affects an individual's nutrient response, influencing athletic performance. Caffeine, present in coffee, tea, chocolate, and guarana, is used to boost stamina and energy. Studies show that the CYP1A2 enzyme metabolizes caffeine, with "fast metabolizers" experiencing pronounced benefits and fewer side effects (Higgins et al., 2016). Vitamin D is crucial for calcium metabolism and bone health, impacting genes like the GC gene and CYP2R1 (Bulgay et al., 2023).

Nutrigenetics explores genetic variation's impact on nutrient metabolism and diet response, helping optimize athletic training and recovery (Guest et al., 2019). Genetic testing identifies gene variants linked to nutrient metabolism, enabling personalized diet plans tailored to athletes' nutritional needs. Variations in caffeine metabolism genes like CYP1A2, ADORA2A, and ACE influence performance, highlighting the need for personalized strategies.

Research indicates specific genotypes in CYP1A2 enhance caffeine's effects on muscle strength and anaerobic performance (Grgic et al., 2020). Meanwhile, studies show that the ADORA2A genotype influences hormonal responses to caffeine, and the ACE genotype affects aerobic power and exertion (Spineli et al., 2024; Rahimi et al., 2023, 2024). Vitamin D and essential fatty acids are vital for bone health and muscle recovery. Genetic variations like the VDR gene (rs2228570) impact how vitamin D affects performance, emphasizing the importance of personalized nutrition (Crescioli, 2022). Understanding genotype effects on nutrient metabolism helps tailor effective dietary and supplementation strategies to support athletes' health and performance (Bulgay et al., 2023).

Overall, while genetic factors modulate the effects of caffeine and vitamin D, their influence varies with context and genotype. Personalized nutrition based on genetic profiles offers potential for enhancing athletic outcomes through tailored dietary and supplementation strategies.

CONCLUSION

This literature review highlights that understanding individual genetic variation can help design more effective nutritional strategies for athletes, enhancing performance and accelerating recovery. Genetic-based approaches to nutrition and supplementation offer great potential to optimize athletic outcomes by tailoring nutrient intake to the specific needs of individuals based on their genetic profiles.

CONFLICT OF INTEREST

The authors declare no competing interests.

FUNDING

There is no funding support.

REFERENCES

Bulgay, C., Bayraktar, I., Kazan, H. H., Yıldırım, D. S., Zorba, E., Akman, O., Ergun, M. A., Cerit, M., Ulucan, K., Eken, Ö., Ceylan, H. İ., Badicu, G., Grosz, W. R., & Mijaică, R. (2023). Evaluation of the Association of VDR rs2228570 Polymorphism with Elite Track and Field Athletes' Competitive Performance. Healthcare (Switzerland), 11(5), 1–11. https://doi.org/10.3390/healthcare11050681

Celis-Morales, C., Marsaux, C. F. M., Livingstone, K. M., Navas-Carretero, S., San-Cristobal, R., Fallaize, R., Macready, A. L., O'Donovan, C., Woolhead, C., Forster, H., Kolossa, S., Daniel, H., Moschonis, G., Mavrogianni, C., Manios, Y., Surwillo, A., Traczyk, I., Drevon, C. A., Grimaldi, K., … Mathers, J. C. (2017). Can genetic-based advice help you lose weight? Findings from the Food4Me European randomized controlled trial. American Journal of Clinical Nutrition, 105(5), 1204–1213. https://doi.org/10.3945/ajcn.116.145680

Communications, S. (2016). Nutrition and Athletic Performance. Medicine and Science in Sports and Exercise, 48(3), 543–568. https://doi.org/10.1249/MSS.0000000000000852

Crescioli, C. (2022). Vitamin D, exercise, and immune health in athletes: A narrative review. Frontiers in Immunology, 13, 954994. https://doi.org/10.3389/fimmu.2022.954994

Glaister, M., Chopra, K., Pereira De Sena, A. L., Sternbach, C., Morina, L., & Mavrommatis, Y. (2021). Caffeine, exercise physiology, and time-trial performance: no effect of ADORA2A or CYP1A2 genotypes. Applied Physiology, Nutrition, and Metabolism = Physiologie Appliquee, Nutrition et Metabolisme, 46(6), 541–551. https://doi.org/10.1139/apnm-2020-0551

Grgic, J., Pickering, C., Bishop, D. J., Schoenfeld, B. J., Mikulic, P., & Pedisic, Z. (2020). CYP1A2 genotype and acute effects of caffeine on resistance exercise, jumping, and sprinting performance. Journal of the International Society of Sports Nutrition, 17(1), 1–11. https://doi.org/10.1186/s12970-020-00349-6

Guest, N. S., Corey, P., Tyrrell, P. N., & El-Sohemy, A. (2022). Effect of Caffeine on Endurance Performance in Athletes May Depend on HTR2A and CYP1A2 Genotypes. Journal of Strength and Conditioning Research, 36(9), 2486–2492. https://doi.org/10.1519/JSC.0000000000003665

Guest, N. S., Horne, J., Vanderhout, S. M., & El-Sohemy, A. (2019). Sport nutrigenomics: Personalized nutrition for athletic performance. Frontiers in Nutrition, 6(February), 1–16. https://doi.org/10.3389/fnut.2019.00008

Heyn, H., Carmona Javier, F., Gomez, A., Ferreira, H. J., Bell, J. T., Sayols, S., Ward, K., Stefansson, O. A., Moran, S., Sandoval, J., Eyfjord, J. E., Spector, T. D., & Esteller, M. (2013). DNA methylation profiling in breast cancer discordant identical twins identifies DOK7 as novel epigenetic biomarker. Carcinogenesis, 34(1), 102–108. https://doi.org/10.1093/carcin/bgs321

Higgins, S., Straight, C. R., & Lewis, R. D. (2016). The Effects of Preexercise Caffeinated Coffee Ingestion on Endurance Performance: An Evidence-Based Review. International Journal of Sport Nutrition and Exercise Metabolism, 26(3), 221–239. https://doi.org/10.1123/ijsnem.2015-0147

Minaei, S., Rahimi, M. R., Mohammadi, H., Jourkesh, M., Kreider, R. B., Forbes, S. C., Souza-Junior, T. P., McAnulty, S. R., & Kalman, D. (2022). CYP1A2 Genotype Polymorphism Influences the Effect of Caffeine on Anaerobic Performance in Trained Males. International Journal of Sport Nutrition and Exercise Metabolism, 32(1), 16–21. https://doi.org/10.1123/ijsnem.2021-0090

Palou, A. (2007). From nutrigenomics to personalised nutrition. Genes and Nutrition, 2(1), 5–7. https://doi.org/10.1007/s12263-007-0022-9

Rahimi, M. R., Semenova, E. A., Larin, A. K., Kulemin, N. A., Generozov, E. V., Łubkowska, B., Ahmetov, I. I., & Golpasandi, H. (2023). The ADORA2A TT Genotype Is Associated with Anti-Inflammatory Effects of Caffeine in Response to Resistance Exercise and Habitual Coffee Intake. Nutrients, 15(7), 1–11. https://doi.org/10.3390/nu15071634

Spineli, H., Pinto, M. P., Dos Santos, B. P., Lima-Silva, A. E., Bertuzzi, R., Gitaí, D. L. G., & de Araujo, G. G. (2020). Caffeine improves various aspects of athletic performance in adolescents independent of their 163 C > A CYP1A2 genotypes. Scandinavian Journal of Medicine & Science in Sports, 30(10), 1869–1877. https://doi.org/10.1111/sms.13749

Spineli, H., Santos, M. Dos, Almeida, D., Gitaí, D., Silva-Cavalcante, M., Balikian, P., Ataide-Silva, T., Marinho, A., Sousa, F., & Araujo, G. de. (2024). ACE gene polymorphisms (rs4340) II and DI are more responsive to the ergogenic effect of caffeine than DD on aerobic power, heart rate, and perceived exertion in a homogeneous Brazilian group of adolescent athletes. Brazilian Journal of Medical and Biological Research = Revista Brasileira de Pesquisas Medicas e Biologicas, 57, e13217. https://doi.org/10.1590/1414-431X2024e13217

Spronk, I., Heaney, S. E., Prvan, T., & O'Connor, H. T. (2015). Relationship Between General Nutrition Knowledge and Dietary Quality in Elite Athletes. International Journal of Sport Nutrition and Exercise Metabolism, 25(3), 243–251. https://doi.org/10.1123/ijsnem.2014-0034

Study, P., Rahimi, M. R., Semenova, E. A., John, G., Fallah, F., Larin, A. K., Generozov, E. V, & Ahmetov, I. I. (2024). Effect of ADORA2A Gene Polymorphism and Acute Caffeine.

Suleman, S., Niaz, A. Q., Akram, M. N., Hadi, B., Usman, M., Sajjad, M., ... & Muqarrab, R. M. (2024). The Role of Nutrigenomics in Sports Performance: A Quantitative Overview of Gene-Diet Interactions. Journal of Health and Rehabilitation Research, 4(1), 1713-1718. https://doi.org/10.61919/jhrr.v4i1.664

Wong, O., Marshall, K., Sicova, M., Guest, N. S., García-Bailo, B., & El-Sohemy, A. (2021). CYP1A2 Genotype Modifies the Effects of Caffeine Compared With Placebo on Muscle Strength in Competitive Male Athletes. International Journal of Sport Nutrition and Exercise Metabolism, 31(5), 420–426. https://doi.org/10.1123/ijsnem.2020-0395.